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Determination of Environmental Factors and Indicator Plant Species for Site Suitability Assessment of Crimean Juniper in the Acipayam District, Turkey

(Penentuan Faktor Persekitaran dan Spesies Tumbuhan Penunjuk bagi Penaksiran Kesesuaian Tapak bagi Juniper Crimea di Daerah Acipayam, Turki)

S. GÜLSOY* & K. ÖZKAN

ABSTRACT

*The present study was carried out to find the environmental and biotic indicators for site suitability of Crimean juniper (*Juniperus excelsa *L.) in the Acıpayam district, Turkey. Data were collected from 100 sample plots. Environmental variables (elevation, slope, radiation index, topographical position, landform characteristics and parent material) and plant species were recorded at each sample plot. Generalised addictive model (GAM) and indicator species analysis (ISA) were applied in order to model the distribution of Crimean juniper and determine the indicator species within its range. The results of the applied GAM analysis and the distribution model obtained showed that most suitable sites for the occurrence of Crimean juniper are the areas in the higher zones (supra and mountain Mediterranean zones) covered by limestone. The results obtained from indicator species analysis (ISA) confirmed the applied GAM results, in the sense that thermo-Mediterranean plant species such as* Arbutus andrachne, Cercis siliquastrum, Cotinus coggyria, Pistacia terebinthus *and* Styrax officinalis *are the negative indicator plant species for Crimean juniper while its positive associates from supra- and mountain-Mediterranean elements are* Berberis crataegiana, Lonicera etrusca *var.* etrusca, Juniperus feoettidissima and Phlomis armeniaca. *These findings are crucial to predict the suitable sites for the utilization of Crimean juniper in afforestration efforts by field managers in degraded and forestless areas of the Acipayam district.*

Keywords: Habitat suitability; Mediterranean region; plant distribution; reforestation

ABSTRAK

*Kajian ini telah dijalankan untuk menentukan penunjuk persekitaran dan biotik bagi kesesuaian tapak bagi juniper Crimea (*Juniperus excelsa *L.) di daerah Acıpayam, Turki. Data telah dikumpul dari 100 plot sampel. Variabel persekitaran (ketinggian, kecerunan, indeks radiasi, kedudukan topografi, sifat bentuk tanah dan bahan induk) dan spesies tumbuhan telah direkodkan di setiap plot sampel. Model adiktif umum (GAM) dan analisis spesies penunjuk (ISA) telah digunakan untuk memperagakan taburan juniper Crimea dan menentukan spesies penunjuk dalam julatnya. Hasil daripada analisis penggunaan GAM dan peraga taburan yang telah didapati menunjukkan bahawa tapak yang paling sesuai bagi kewujudan juniper Crimea adalah di kawasan zon tinggi (zon supra dan pergunungan Mediterranean) yang dilitupi oleh batu kapur. Hasil yang diperoleh daripada analisis spesies penunjuk (ISA) mengesahkan hasil daripada penggunaan GAM, dalam erti kata spesies tumbuhan termo-Mediterranean seperti* Arbutus andrachne, Cercis siliquastrum, Cotinus coggyria, Pistacia terebinthus *dan* Styrax officinalis *adalah spesies tumbuhan penunjuk negatif bagi juniper Crimea manakala sekutuan positif daripada unsur supra- dan pergunungan Mediterranean adalah* Berberis crataegiana, Lonicera etrusca *var.* etrusca, Juniperus feoettidissima *dan* Phlomis armeniaca. *Penemuan ini adalah penting untuk meramal tapak yang sesuai bagi penggunaan juniper Crimea dalam usaha penghutanan oleh pengurus lapangan di kawasan tanpa hutan dan hutan miskin bagi daerah Acipayam.*

Kata kunci: Kesesuaian habitat; penghutanan semula; taburan tumbuhan; wilayah Mediterranean

INTRODUCTION

Juniperus genus belongs to the Cupressaceae family, having more than 140 species in three different sub-families (Thujoideae, Cupressoideae and Juniperoideae). In Turkey, junipers are represented by 7 native species which are divided into two sections called oxycedrus (*J. oxycedrus* L., *J. communis* L. and *J. oblonga* Bieb) and sabina (*J. sabina* L., *J. foetidissima* Willd., *J. phoenicea* L. and *J. excelsa* M. Bieb) (Davis 1965; Gültekin & Gültekin 2007). One of these is *Juniperus excelsa* M. Bieb (Crimean Juniper) known locally as 'Boylu or Boz Ardıç'. It is an evergreen tree or occasionally a shrub, up to 20-25 m. Tall, slow growing, pyramidal in shape during early stages of growth, but with broad crown at later stages of growth (Farjon 2005). The species is important economically and from the industrial point of view due to its heartwood which is highly durable and is aromatic.

Crimean Juniper is distributed in Turkey, Lebanon, Iran, Syria and Greece (Quézel & Médail 2003). It is the most common native tree species after pines and oaks throughout the Taurus Mountain range in Turkey, covering nearly 82% of total 1.2 million ha juniper forests in the country (Gültekin & Gultekin 2007; Özkan et al. 2010). The species is adapted to a wide range of sites; including mountainous, dry and rocky areas from 1000 m up to the tree-line and beyond in the cold Mediterranean zones (Adams 2004). It can tolerate severe drought and cold conditions and can subsist on the shallow soils on degraded habitats (Douaihy et al. 2011).

Most of the Crimean juniper forests have suffered much from the prehistoric period due to overgrazing, deforestation, fires and inappropriate agricultural practices (Carus 2004; Yücedağ et al. 2010). Throughout the distribution range of the Crimean juniper, the species can sometimes suffer from insects, mistletoe and fungal attacks (Gardner & Fisher 1996). Both natural and artificial regeneration of the species is crucial due to poor seed germination (Avsar & Tonguc 2003), due to their fleshy cone, hard seed coat, immature and unfilled seed and embryo dormancy. In the recent years, many studies have been conducted on their seed dormancy and germination problems (Al-Refai et al. 2003; Esmaeelnia et al. 2006; Gülcü & Gültekin 2005; Gültekin & Öztürk 2003; Gültekin et al. 2003); but it is obvious that these efforts have not fully overcome the problem for their sustainability in the forests (Lee et al. 1995). Therefore, studies to determine the suitable environmental factors and indicator plant species for site suitability of the Crimean juniper are needed (Fontaine et al. 2007).

We have hypothesized that determination of site properties and indicator plant species for the Crimean juniper will be useful in decision making in forest restoration management (Özkan et al. 2010). The main objective of the present study were to determine the site requirements and exhibit the indicator plant species for site suitability of the Crimean juniper in the Acipayam district of Turkey.

MATERIALS AND METHODS

STUDY SITE

The study was conducted in Crimean juniper forests of Acipayam district located between 400 and 2000 m above sea level. Acipayam district covers an area of 2365 km^2 in the south-western Anatolia between 37º45'N latitude and 28º98' E longitude, as per UTM coordinate system (Figure 1). The highest peaks are Honaz (2528 m) and Bozdağ (2419 m) mountains in the north of the study area. Dalaman stream divides the study area into two parts, northwest and southeast directions and Gireniz valley runs from northeast to southwest in the district.

Acipayam district experiences a cool and sub-humid Mediterranean climate with winter precipitation and summer droughts (Özkan 2009). The closest meteorological station is situated at an elevation of 941 m above sea level in Acipayam district. According to the measurements of this station from 1970 to 2003, average annual precipitation is approximately 520 mm year^{-1}, received mainly during winter as snowfall, mean yearly temperature is 12.5ºC and the mean monthly temperate ranges between 2.0ºC (January) and 24.4ºC (July). Annual

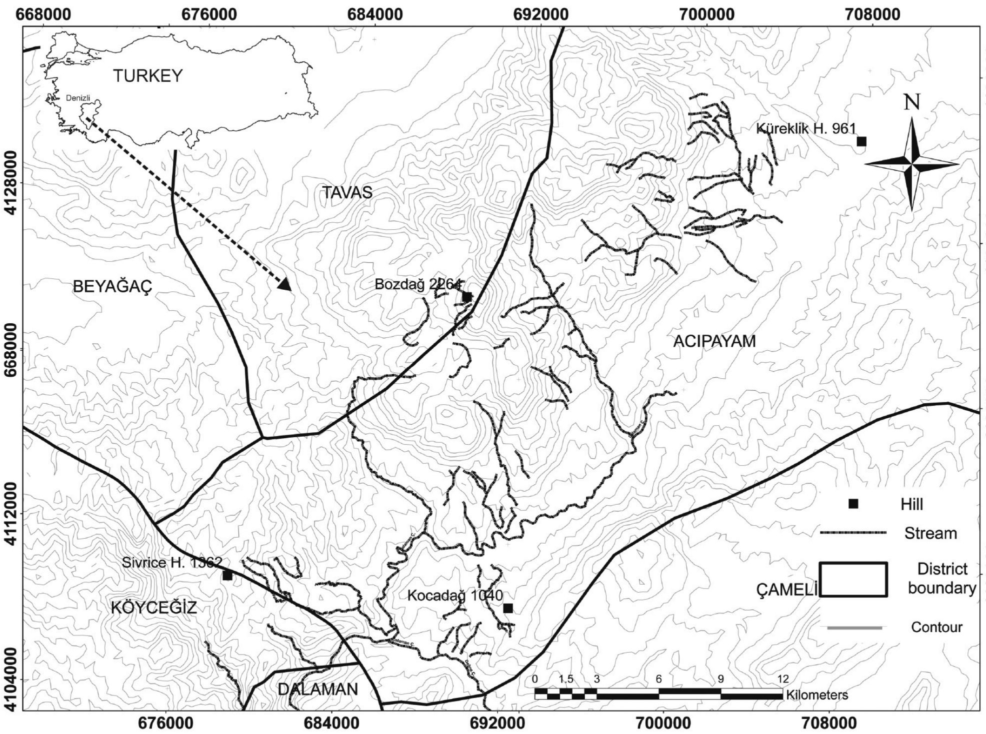

FIGURE 1. Map of the study site in the Acipayam district, Denizli Province, Turkey

average wind speed is around 6.5 m per s and 44% of the prevailing wind direction for the area is in the north and west directions during the year (DMI 2003).

Besides some undifferentiated formations, the rock underlayer is typically composed of Mesozoic and Palaeozoic limestone blocks, Mesozoic aged serpentines, Neolithic aged marl and conglomerate blocks (MTA 1974; Özkan 2009). Parent material is characterized by lime stone in the study area. Soils are classified as leptosols, regosols and cambisols and soil characteristics such as soil depth, moisture content, stoniness, texture and structure locally vary with topography and parent material (FAO et al. 1998).

The Mediterranean forest types are dominant in the study area. The forest area covers a total area of about 101.449 ha, 63.957 ha of which is productive and 37.492 ha unproductive. The remainder (about 87880 ha) is open area utilized for agricultural and settlement purposes. The occurrence of tree species across the elevation gradient in the study area is mostly related to the latitudinal features. The study area is covered by *Pinus brutia* Ten. forests at lower elevations (400-800 m); *Pinus nigra*, *Juniperus* sp. and *Quercus* sp. generally occur at middle elevations (800-1600 m) and *Cedrus libani* rich forests together with *Juniperus* sp. start at upper zones of middle elevations and go up to 2000-2100 m elevations.

DATA COLLECTION

One hundred sample plots were used in the study. *J. excelsa* had distribution in forty-five of these plots. The location of these 20 × 20 m^2 dimension sample plots was recorded using GPS and transcribed on the topographic maps with 1/25000 scale (Figure 2). Elevation for each sample plot were numerically recorded using altimeter (m) and slope degree recorded with clinometer (%). Aspect values were determined with compass (θ) and transformed to radiation index (RI) values with formula TRASP = $[1 - \cos((\pi/180)(\theta\text{-}30))]/2$ which is between 0 and 1 (Aertsen et al. 2010). The slope positions were coded from flat areas or valley bottoms to the ridges through a slope and respectively converted to numeric values as 1 (flat/valley bottom), 2 (lower slope), 3 (middle slope), 4 (upper slope) and 5 (ridge) before statistical evaluation. Four landform types were recorded: concave, convex, linear and undulate from the areal studies and respectively converted into 1, 2, 3 and 4 numeric values. Besides undifferentiated formations four bedrock types were determined during the areal studies and converted to numeric values as 1 (limestone), 2 (serpentine), 3 (conglomerate), 4 (marl) and 5 (other bedrock types). Heat index was also used and explanatory variables calculated for each sample plot with the following equation $HI = \cos alpha1 * \tan alpha2$; where, *alpha*1 is deviation of aspect from 202.5^0 (SSW) and *alpha*2 is slope degree (Parker 1988). Before statistical analysis, all these plots were coded as s1, s2, s3, …s100 and environmental parameters from these plots are given with their codes in Table 1.

Plant species in the sample plots were recorded with their scientific names according to the presence or absence within the plots as vegetation matrices. Seventy seven different plant species were identified from the plots. They were taken for the statistical analysis to determine indicator species of Crimean juniper. Scientific names of all these plant species are given with their codes in Appendix 1.

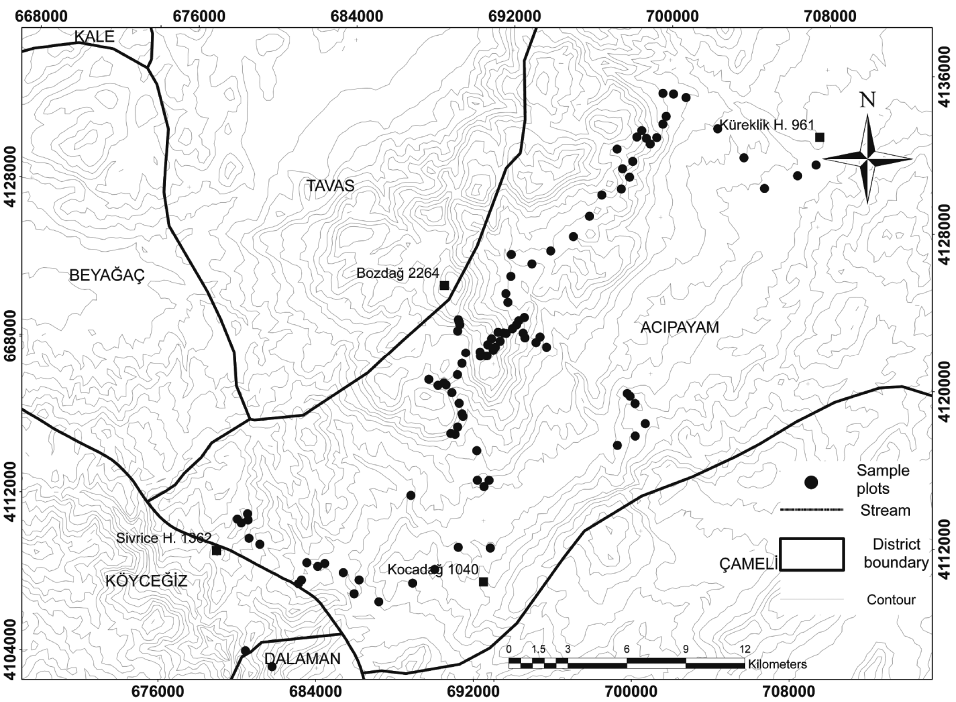

FIGURE 2. Location of the sample plots in the study area

TABLE 1. Environmental variables and their codes
(n: continuous data, c: categorical data)

Variables	Codes
Elevation (n)	ELVN
Slope degree (n)	SLPD
Radiation index (Aspect) (n)	RI
Heat index	HI
Bedrock types (c)	ROCK
Landform category (c)	LNDF
Slope position (c)	SLPP

APPENDIX 1. The scientific names and abbreviations of plant species determined from the sample plots

Species	Codes	Species	Codes
Acantholimon sp.	Acansp	*Ononis spinosa* L.	Onospi
Acer monspessulanum L.	Acemon	*Origanum hypericifolium* O. Schwarz	Orinan
Acer sp.	Acersp	*Prunus divaricata* Ledeb.	Prudiv
Althaea rosea L.	Altros	*Paeonia* sp.	Paesp
Amygdalus orientalis Miller.	Amyori	*Phlomis armeniaca* Willd.	Phlarm
Arbutus andrachne L.	Arband	*Phlomis grandiflora* H.S. Thampson	Phlgra
Arum maculatum L.	Arumac	*Pinus brutia* Ten.	Pinbru
Astragalus microcephalus Willd.	Astmic	*Pinus nigra* Arn. ssp. *pallisiana* (lamb.) Holmboe	Pinnig
Astragalus sp.	Astrsp	*Pyrus communis* L.	Pircom
Berberis crataegina DC.	Bercra	*Pyrus elaeagnifolia* Pallas.	Pirela
Bromus sp.	Brosp	*Pistacia terebinthus* L.	Pister
Lonicera etrusca Santi var. *etrusca*	Lonetr	*Platanus orientalis* L.	Plaori
Carduus nutans L.	Carnut	*Populus tremula* L.	Poptre
Cedrus libani A. Rich.	Cedlib	*Prunus spinosa* L.	Pruspi
Cercis siliquastrum L.	Cersil	*Quercus cerris* L. var. *cerris*	Quecer
Cirsium arvense (L.) Scop.	Cirarv	*Quercus coccifera* L.	Quecoc
Cistus creticus L.	Ciscre	*Quercus ilex* L.	Queile
Cistus salviifolius L.	Cissal	*Quercus infectoria* Olivier.	Queinf
Colutea arborescens L.	Colarb	*Quercus trojana* P. B. Webb	Quetro
Cotoneaster nummularia Fisch. Et Mey.	Cotnum	*Rhamnus oleoides* L.	Rhaole
Cotinus coggyria Scop.	Cotcog	*Rhus coriaria* L.	Rhucor
Crataegus monogyna L.	Cremon	*Rosa canina* L.	Roscan
Daphne sericea Vahl.	Dafser	*Rubus fruticosus* L.	Rubfru
Digitalis davisiana Heywood.	Digdav	*Salix alba* L.	Salalb
Dryopteris pallida (Bory) Fomin.	Drypal	*Salvia officinalis* L.	Saloff
Echinops viscosus DC. subsp. *bithynicus*	Echvis	*Satureja cuneifolia* Ten.	Satcun
Erica verticillata Forsk.	Eriver	*Scolymus hispanicus* L.	Scohis
Eryngium sp.	Erysp	*Spartium junceum* L.	Spajun
Euphorbia sp.	Euhorb	*Styrax officinalis* L.	Styoff
Fontanesia philliraeoides Labill. subsp.	Fonphil	*Tamarix smyrnensis* Bunge.	Tamsmy
philliraeoides			Taxbac
Fraxinus ornus L.	Fraorn	*Taxus baccata* L.	
Inula anatolica Boiss.	Inuana	*Thymbra spicata* L.	Thyspi
Juniperus excelsa Bieb.	Junexc	*Thymus longicaulis* C. Presl.	Thylon
Juniperus foetidissima Willd.	Junfeo	*Ulmus glabra* Hudson.	Ulmgla
Juniperus oxycedrus L.	Junoxy	*Urtica dioica* L.	Urtdio
Liquidambar orientalis Mill.	Liqoir	*Verbascum* sp.	Verbas
Marrubium vulgare L.	Marvul	*Vicia sativa* L.	Vicsat
Mentha spicata L.	Menspi	*Xanthium spinosum* L.	Xanspi
Morus alba L.	Moralb		

DATA ANALYSIS

Generalized additive model (GAM) has been increasingly used to determine the environmental factors and plant distribution relations. In this study GAM was performed to determine the effects of the environmental factors on the distribution of Crimean juniper. A quasi-binominal model was chosen and an Anova (F-test) for quasi models was used to test the significance of the smooth terms (Lehmann et al. 2002). To evaluate the GAM model, Receiver Operating Characteristic (ROC) curves were produced using the Area under the ROC Curve (AUC) and commonly used evaluation statistics of binominal model performance (Fielding & Bell 1997). Indicator species analysis (ISA) was employed to find indicator plant species for the Crimean juniper (Dufrêne & Legendre 1997).

RESULTS

During this study, the best model for the distribution of Crimean juniper was obtained by means of ROCK and ELVN. The stepwise selection of predictors for the distribution of Crimean juniper selects the following model.

The occurrence of probability = ROCK + s (ELVN, 4) *(explained deviance : 55%),*
where s is the spline smoother, 4 is d.f. for the spline smoother.

The validation results of the model are given in Figure 3. The results for the cross-validation and simple validation of Crimean juniper are represented quite good in ROC and cvROC values (ROC and cvROC values >0.8). On the other hand, the smaller difference of the values between COR (Sperman Correlation) and cvCOR denotes the high model stability.

The contribution rates of the significant variables to the final model are shown in Figure 4. When dropping each predictor from the final model, ROCK and ELVN contributes 14.31% and 30.62%, respectively. The contribution of ROCK and ELVN alone were found to be 45.98% and 62.28%, respectively. Contribution values (10.27% and 16.20%, respectively) inside the model were lower than other models but the contribution rates of ELVN is still bigger than ROCK.

The partial response of the predictors is given in Figure 5. Preference of the Crimean juniper in the area is characterised by significant positive response to ROCK-1 (limestone) and ELVN. This situation is also supported by the environmental space occupied by the histograms in Figure 6. In the histograms, the grey and black portions of the bar show the sample plots without and with Crimean juniper, respectively. The solid line shows the proportion of the sample plots in each bar that includes one or more Crimean juniper site, relative to the overall average proportion of the sample plots with Crimean juniper which is shown by the dashed line. It means that where the solid line is above, the dashed line is more suitable for the preference of Crimean juniper. The histograms clearly depict that site preference of Crimean juniper in the district is widely characterized by higher altitudes (above 1600 m) and limestone parent material.

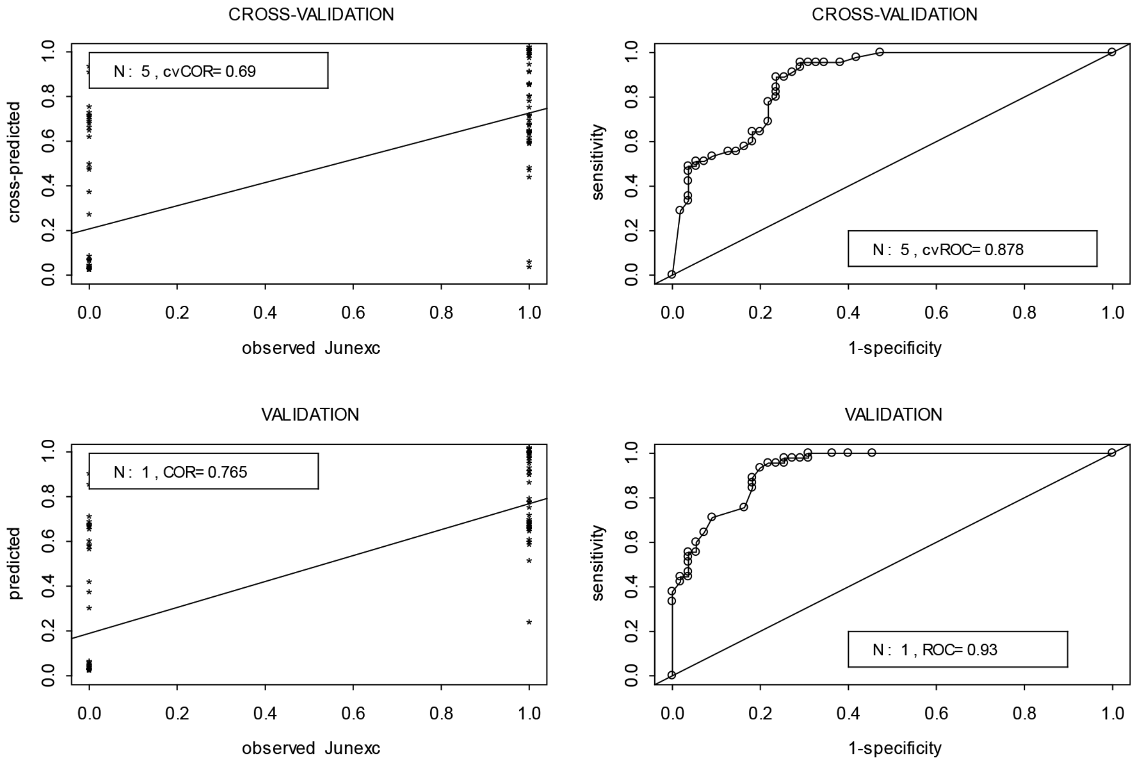

FIGURE 3. Validation of the model with AUC values for ROC and cvROC (cross-validated ROC)

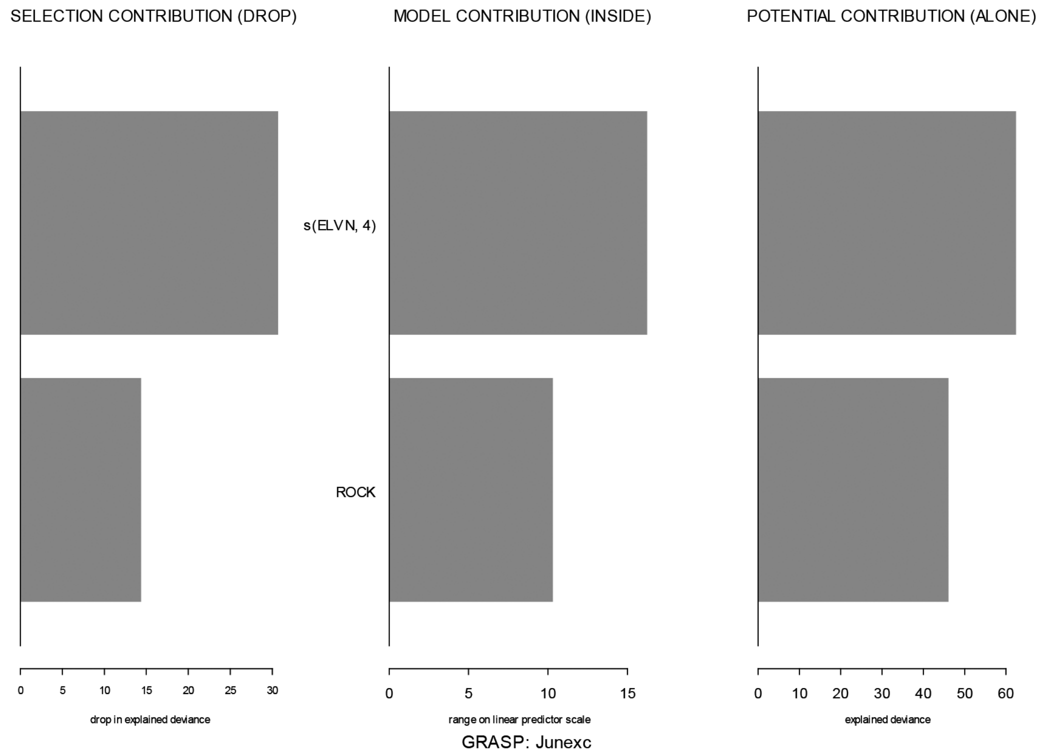

FIGURE 4. Contributions of the predictor variables to the model

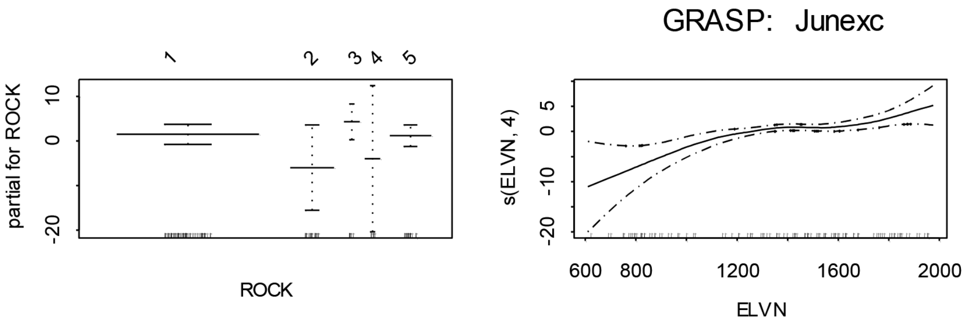

FIGURE 5. Response curves of the presence/absence to the predictor variables in the GAM analysis (The y-axes are based in partial residuals and indicate the relative influence of each explanatory variable on the prediction)

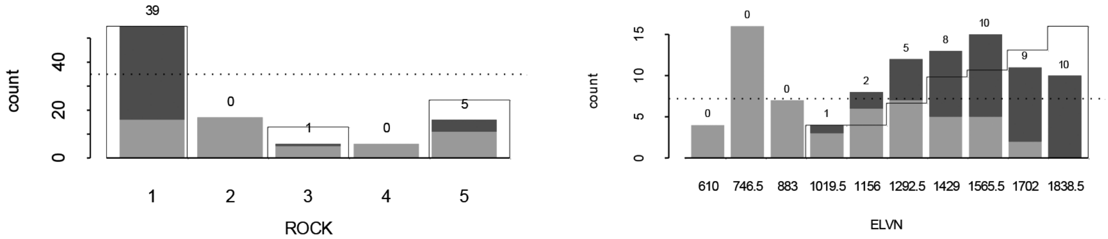

FIGURE 6. Histograms of the predictor variables to the model

A total of 77 plant species were recorded from 100 sample plots. After indicator species analysis (ISA), 18 plant species among these were detected as an indicator for the Crimean juniper. *Acantholimon* sp, *Berberis crataegina* DC., *Lonicera etrusca* Santi var. *etrusca* Santi, *Euphorbia* sp., *Juniperus foetidissima* Willd., *Phlomis armeniaca* Willd., *Taxus baccata* L., *Verbascum* sp. and *Vicia sativa* L. were found positive indicator while *Arbutus andrachne* L., *Astragalus microcephalus* Willd., *Cercis siliquastrum* L., *Cotinus coggyria* Scop., *Pinus brutia* Ten., *Pistacia terebinthus* L., *Platanus orientalis* L., *Quercus infectoria* Olivier. and *Styrax officinalis* L. were determined as negative indicators for Crimean juniper at a level of 5% significance (Table 2).

Discussion

Turkey is one of the countries which has the biggest pure stands of Crimean juniper in the world. It is one of the most resistant tree species in the upper elevations of the highlands of South Anatolian, ranging from about 1200 to 3000 m in the region and generally forms pure and open mono-specific stands in the wild, but grows extremely slow with poor natural regenerations (Sarangzai et al. 2012). It is also known as long-lived tree and drought resistant tree species in the world (Sheikh 1985). For many years, it has been a source of timber and fire wood and juniper forests have been degraded through over-grazing, excessive cutting for timber, fire and human settlements in Turkey (Fontaine et al. 2007; Kargioglu et al. 2010). Therefore, its distribution areas have been restricted by many misapplications leading to an increased rate of soil erosion (Moinuddin et al. 1990). It is therefore very important to conduct comprehensive studies in particular the ecology of Crimean juniper for its sustainability.

Some comprehensive quantitative studies have been done on its ecology in recent years. One of these is the investigations on the site properties of Crimean juniper in semi-natural forests of south western Anatolia (Özkan et al. 2010). Another significant study on the ecology and dynamics of *Juniperus excelsa* forest is that of Sarangzai et al. (2012). The present study was conducted to fill the gap and provide valuable information for understanding the distribution of Crimean juniper in the region.

According to GAM analysis conducted during this study regarding the common site properties of Crimean juniper, elevation and bedrock types were found to be the most important factors. It is also apparent that Crimean juniper prefers higher elevations and limestone sites in the district. Pirani et al. (2011) described that it could survive under harsh climate conditions of higher elevations of the mountainous areas and could be considered as the most dominant tree species in such habitats. They also pointed out that it grew mainly on stony and rocky calcareous slopes. Özkan et al. (2010) too have concluded that elevation and surface stoniness were the most significant variables determining the distribution of Crimean juniper. The findings in the present study are also supported by the results of other works on the relationship between environmental factors and the distribution of *J. excelsa* (Moinuddin et al. 1990; Sarangzai et al. 2012).

A total of nine plant species were determined by ISA during this study which were positive indicatory species for *J. excelsa*. Another nine species were negatively associated with this species namely; *P. brutia* Ten. (0 to 1200 m), *C. coggyria* Scop. (0 to 1300 m) and *S officinalis* L. (0 to 1500 m) with distribution ranging between 0 and 1500 m. These were the most negative indicatory species whereas *J. foetidissima* Willd. (700 to 1900 m), *P. armeniaca* Willd. (800 to 2300 m) and *B. crataegina* DC.

TABLE 2. The results of indicator species analysis (ISA) applied to determine the indicator species of Crimean juniper

Names of the species	Codes	Group	Value	Mean	SD	p
Acanthalimon sp.	Acansp	1	13.9	6.6	2.09	0.016
Arbutus andrachne L.	Arband	0	12.7	6.0	2.20	0.020
Astragalus microcephalus Willd.	Astmic	0	10.9	5.3	1.92	0.029
Berberis crataegiana DC.	Bercra	1	31.7	14.2	3.05	0.001
Lonicera etrusca Santi var. *etrusca*	Lonetr	1	13.3	5.4	2.00	0.006
Cercis siliquastrum L.	Cersil	0	12.7	6.1	2.17	0.015
Cotinus coggyria Scop.	Cotcog	0	32.7	12.5	2.99	0.001
Euhorbia sp.	Euhorb	1	39.1	16.7	3.03	0.001
Juniperus feoettidissima Wild.	Junfeo	1	40.5	13.6	3.11	0.001
Phlomis armeniaca Willd.	Phlarm	1	33.0	13.5	3.02	0.001
Pinus brutia Ten.	Pinbru	0	64.8	26.3	3.47	0.001
Pistacia terebinthus L.	Pister	0	16.2	8.5	2.61	0.022
Platanus orientalis L.	Plaori	0	10.9	5.5	1.99	0.035
Quercus infectoria Olivier.	Queinf	0	23.7	13.1	2.91	0.011
Styrax officinalis L.	Styoff	0	23.4	10.7	2.59	0.001
Taxus baccata L.	Taxbac	1	15.6	6.1	2.12	0.002
Verbascum sp.	Verbas	1	36.5	24.7	3.31	0.007
Vicia sativa L.	Vicsat	1	18.3	7.9	2.38	0.006

(800-1500 m) which have distribution range between 700 and 2300 m, were the most accompanying species for the distribution of Crimean juniper in the district. Although its positive indicator species are mainly characterized by cold and humid mountainous Mediterranean plant communities (average annual temperature is 7-4°C), negative indicator species are the elements of Eu-Mediterranean (average annual temperature is 20-16°C) and Sub-Mediterranean plant communities (average annual temperature is 12-15°C) (Atalay & Efe 2008; Fontaine et al. 2007). Similar results have been reported in this connection in the studies concerning the ecological properties of Crimean juniper carried out in the Aglasun district and Beysehir watershed areas by Özkan and Çelik (2008) and Özkan et al. (2010).

Conclusion

Our results showed that Crimean juniper forests particularly prefer the sites above 1000 m, where more humid mountainous Mediterranean climate predominates. It is considered as very cold resistant tree species. The species is exposed to human disturbances threatening its future occurrence in the forests. Therefore proper forest restoration managements and applications are strictly necessary for its protection.

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